



22-17-00

IBM Docket No. RAL9-99-0181

JC530 U.S. PTO
09/505748

02/16/00

In the United States Patent and Trademark Office Patent Application Transmittal

Transmitted herewith for filing is the Patent Application of:

Inventors(s): Raj Kumar Singh, Laura Ann Weaver

For: Customizable Simulation Model of an ATM/SONET Framer for System Level Verification
and Performance Characterization

Enclosed are

21 pages of specification, including 12 claims, plus 2 sheets of drawings.

An assignment of the invention to International Business Machines Corporation, Armonk, New York 10504.

A certified copy of a/an application.

Declaration and Power of Attorney.

PTO-1449 & references

A return post card

Other:

Filing Fee Calculation (For Other Than Small Entity)

Basic Fee:					\$760.00
Claims Fees:	Filed	Limit	Extra	Rate per Extra	
Total claims:	12	20	0	\$18.00	\$0.00
Independent claims:	2	3	0	\$78.00	\$0.00
	Multiple Dependent Claim Presented			\$260.00	\$0.00
				Total	\$760.00

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CUSTOMIZABLE SIMULATION MODEL OF AN ATM/SONET FRAMER FOR
SYSTEM LEVEL VERIFICATION AND PERFORMANCE
CHARACTERIZATION

Technical Field

5 The technical field of this invention relates to a
customizable model of an ATM/SONET Framer for system
level verification and performance characterization with
programmable FIFO status update and clock domain
synchronization.

10

Background of the Invention and Prior Art

 A system level simulation requires use of behavioral
models representing functionality of commercial
off-the-shelf MAC devices from many vendors. Such
15 behavioral models are generally not available from the
device vendors. A solution to this problem commonly
suggested by the device vendors is to use the actual
Register Transfer Level (RTL) or gate level design MODEL
implemented in a Hardware Description Language (HDL) such
20 as Verilog or VHDL. However, using a non-behavioral
model in a simulation results in significant degradation
of simulation performance. Moreover, integration of the
actual design model or vendor supplied behavioral model

5 in the local simulation limits observability and
controllability due to constraints stemming from the
protection of proprietary data. A practical alternative
to this problem is to develop an accurate custom
behavioral model that offers sufficient parameters which
10 can be programmed to represent framers from different
vendors.

Summary of the Invention

The present invention describes the architecture and
implementation of a behavioral VHDL model of an ATM/SONET
15 framer. The model is comprised of two independently
configurable components, a Receiver and a Transmitter,
and offers flexibility to allow testing with multiple
vendors' of framers by changing programmable parameters
of the model.

20 The present invention represents a customizable
simulation model of an ATM/SONET Framer for System Level
Verification and Performance Characterization. An
asynchronous Transfer Mode (ATM) data processing ASIC
interfaces with a Media Access Control (MAC) device that
25 presents an electrical data path interface, called
Universal Test & Operations PHY Interface for ATM
(UTOPIA), using ATM protocol on the ASIC side and simplex

5 optical interfaces using synchronous Optical Network
(SONET) protocol on the network side. Such a MAC device,
commonly referred to as ATM/SONET Framer, provides one
Receive and one Transmit interface to the network at
various SONET line rates such as 155.52 Mbps(OC-3),
10 622.08 Mbps(OC-12), 2488.32 Mbps(OC-48), etc. The ATM and
the SONET interfaces operate on different clock
frequencies and thus represent two distinct clocking
domains. The data interchange between the two clocking
domains is achieved via FIFO buffer elements and
15 associated control and status signals.

Brief Description of the Drawings

Fig. 1 This figure represents the basic
architecture of the ATM/SONET FRAMER.

20

Fig. 2 This represents SONET OC-Nc FRAME
Structure.

Detailed Description of the Preferred Embodiment

25 Before going into the details of the present
invention, it would be quite helpful to the reader to

5 have several terms of art defined. These are listed
below:

Definitions

10 Sonet This is an acronym for Synchronous
Optical Network. A category of fiber optic communication
standards that permits extremely high speed transmission
(51.84 Mbps to 24488 Mbps) .

15 ATM This is referred to as an Asynchronous
Transfer Mode.

15 MAC is defined as the acronym, Media Access
Control.

15 HDL is defined as the acronym, Hardware
Description Language.

15 RTL is defined as the acronym, Register
Transfer language.

20 VHDL & Verilog are considered as hardware
description language.

25 As noted above, an Asynchronous Transfer Mode (ATM)
data processing ASIC interfaces with a Media Access
Control (MAC) device that presents an electrical data
path interface, called Universal Test & Operations PHY
Interface for ATM (UTOPIA), using ATM protocol on the

5 ASIC side and simplex optical interfaces using
Synchronous Optical Network (SONET) protocol on the
network side. Such a MAC device, commonly referred to as
ATM/SONET Framer, provides one Receive and one Transmit
interface to the network at various SONET line rates such
10 as 155.52 Mbps(OC-3), 622.08 Mbps(OC-12), 2488.32
Gbps(OC-48), etc. The ATM and the SONET interfaces
operate on different clock frequencies and thus represent
two distinct clocking domains. The data interchange
between the two clocking domains is achieved via FIFO
15 buffer elements and associated control and status
signals.

A system level simulation requires use of behavioral
models representing functionality of commercial
20 off-the-shelf MAC devices from many vendors. Such
behavioral models are generally not available from the
device vendors. A solution to this problem commonly
suggested by the device vendors is to use the actual
Register Transfer Level (RTL) or gate level design
25 implemented in a Hardware Description Language (HDL) such
as Verilog or VHDL. However, using a non-behavioral
model in a simulation results in significant degradation

5 of simulation performance. Moreover, integration of the actual design model or vendor supplied behavioral model in the local simulation limits observability and controllability due to constraints stemming from the protection of proprietary data. A practical alternative
10 to this problem is to develop an accurate custom behavioral model that offers sufficient parameters which can be programmed to represent framers from different vendors.

15 The present invention describes the architecture and implementation of a behavioral VHDL model of an ATM/SONET framer. The model is comprised of two independently configurable components, a Receiver and a Transmitter, and offers flexibility to allow testing with multiple
20 vendors' of framers by changing programmable parameters of the model.

The present invention functions in the following manner. The basic architecture of the ATM/SONET FRAMER is shown in Fig. 1.

25 The invention offers the advantages of programmability, rich features set, and two independently configurable models, one each for transmit and receive

5 side. The programmability of the models extends beyond what is necessary to capture the functionality of commercial vendor devices. The programmable features include:

- SONET line rates (OC-Nc: N=1..48; OC-1=51.48
10 Mbps)
- Percentage of data bytes vs. overhead bytes per row
- Delays associated with clock domain synchronization
- 15 • FIFO depth and threshold (in terms of number of cells)
- Byte or word count threshold within a cell associated with FIFO status update
- UTOPIA Level-2/3
- 20 • Built-in performance checking

Framer Transmit Model

Features

- Insert ATM cells into a transmitted OC-Nc frame
- 25 • Insert idle cells for rate adaptation
- Provide interface setup and hold time checks
- Provide performance check

5 . Generate error messages if Utopia FIFO overrun
 or underrun during performance check
 . Programmable Tx FIFO depth and threshold
 . Latency associated with clock domain
 synchronization
10 . Programmable SONET rate

Description

The basic architecture of the ATM/SONET FRAMER is shown in Figure 1. The component represented as seen in the Fig. 1 are the network connections at location 100, 15 the UUT (ATM Data Processor) at location 101, the Framer at 102, the ATM Clock Domain at location 103, the SONET Clock Domain at location 104.

Fig. 1, shows the implementation of transmit model, 20 located at 105, which is implemented as a set of sixteen, per-port UTOPIA Tx FIFOs whose depth is settable by a generic parameter on the model, and a set of sixteen "virtual" network queues of infinite depth.

25 A UTOPIA Tx Level-2/3 physical bus interface process implements the utopia slave protocol and supports cell-level handshake and data transfer. Each cell

5 received from the UTOPIA Master Tx, location at 106, interface on the ATM UUT is written into the appropriate per-port UTOPIA Tx FIFO in the framer. The cell is then read out of the UTOPIA Tx FIFO (into the corresponding "virtual" network queue) based on a SONET framer process
10 which follows the SONET overhead and SONET payload envelope (SPE) structure as shown in Fig. 2. There is one framer process per UTOPIA port. Each framer process can be configured independent of the others. Since multiple framers in a real system will power-up at random
15 times, each framer process uses a built-in random delay between zero ns and one row time before starting to generate the virtual OC-Nc frames.

20 These framer processes constitute the core of the transmit model. Each process is synchronous to the SONET byte clock(which is programmable via the line rate parameter), and maintains a count of the cells received into the corresponding UTOPIA Tx FIFO. The process mimics
25 the SONET frame structure by maintaining a running count of the overhead bytes received for a row, the count of data bytes received for the cell, and the count of rows

5 within the fixed 125 micro-second frame length. When the running count of data bytes received for a cell equals 53 (the number of bytes in an ATM cell) the cell count in the UTOPIA Tx FIFO is decremented.

Since, the SONET frames length is independent of the 10 SONET data rate and fixed at 125 micro-seconds , the parameters such as the number of bytes in a row and the number of bytes in SONET payload envelope can be modified by programming different values of the line rate, and/or the percentage of data bytes in a row. These values may 15 be set from a test case via a procedure call to the framer model.

Many vendors' framer provide programmability in FIFO status update during Write and Read. A cell is generally 20 not transmitted until the complete cell has been written into the Tx FIFO. The programmability feature allows the cell count to be incremented before the entire cell is physically transferred. This is specified in terms of number of words transferred across the UTOPIA interface. 25 The model supports this programmability via a generic. Similarly, the cell count is decremented when a complete cell from Tx FIFO is inserted into the SONET frame. The

5 cell count can be decremented at a programmable byte
count into the ATM cell structure. This feature is also
supported via a different generic. Two additional
generics have been included in the model to mimic the
synchronization delay between ATM and SONET clock
10 domains. These two generics represent the latency
associated with propagation and registration of FIFO
status (cell count) update across the ATM/SONET domain
boundary in each direction.

15 This model can be programmed to handle UTOPIA
Level-2/3 via a generic. Each port can be programmed to
emulate a particular SONET line rate (0 to 2488.32 Mbps).

Framer Receive Model

20 Features

- Extract ATM cells from the received OC-Nc frame format.
- Strip idle cells
- Purge enqueueued cells
- 25 • Provide interface setup and hold time checks
- Provide performance check on the line side

5 . Generate error messages if UTOPIA Rx FIFO overrun
 or underrun during performance check

 . Programmable Rx FIFO depth and threshold

 . Latency associated with clock domain
 synchronization

10 . Programmable SONET rate

Description

As shown in Fig. 1, the SONET receive model is implemented as two logical sets of sixteen, per-port
15 FIFOs. The sixteen network FIFOs are infinitely deep. The depth of UTOPIA Rx FIFOs defaults to a value of four cells, and can be modified via a procedure call.

ATM cells are enqueued to the receive model via a
20 procedure call from a test case, and are placed in the appropriate per-port network FIFO. The cell is then read out of the network FIFO and written into the corresponding UTOPIA Rx FIFO based on a framer process which mimics the SONET overhead and payload envelope
25 structure. There is one framer process for each port, and each framer process can be configured independently of the others. A UTOPIA Rx Level-2/3 physical bus

5 interface process implements the slave protocol and
supports cell-level handshake and forwards the cells from
UTOPIA Rx FIFO to the UUT.

The framer processes are synchronous to the SONET
10 byte clock, which is programmable via the line rate, and
maintains a count of data bytes (versus overhead bytes)
in a cell, and a count which represents the number of
rows in a 125 micro-seconds SONET frame. On the
simulation start-up, these processes delay a random
15 amount of time (between 0 ns and one row time) before
starting to emulate extraction of ATM cells from the
SONET frame structure in order to mimic the random start
of different framers.

20 A cell is received into the UTOPIA Rx FIFO and cell
count incremented when the count of data bytes in a cell
extracted from the SONET frame equals a generic
parameter. The default value of this parameter is set to
53. Similarly, when the count of words in a cell which
25 have been transferred across the UTOPIA Rx bus equals
another generic, the count of cells in the UTOPIA Rx FIFO
is decremented. The synchronization delay between ATM and

5 SONET clock domains, observed in real framer
implementations, is modeled by two additional generics.
These two generics represent the latency associated with
propagation and registration of FIFO status (cell count)
update across the ATM/SONET domain boundary in each
10 direction.

This model can be programmed to handle UTOPIA
Level-2/3 via a generic. The model supports
randomization of ATM cell payload. Each port can be
programmed to emulate a particular SONET line rate (0 to
15 2488.32 Mbps).

While the invention has described with respect to a
specific embodiment, it will be obvious to those skilled
in this art that changes in both form and/or detail may
be made without a departure from the scope and/or spirit
20 of the invention.

We claim:

Claims

1 1. A computer based system employing a
2 customizable Simulation Model of an ATM/SONET Framer, for
3 system level verification and performance
4 characterization, comprising:

5 means for developing an accurate customizable
6 behavioral model that offer sufficient parameters which
7 can be programmed to represent Framers from different
8 vendors;

9 means for providing two independently configurable
10 components, a Receiver and a Transmitter,
11 and

12 which provide testing with said multiple vendors of
13 Framers, by changing programmable parameters of said
14 model.

1 2. The system of claim 1 wherein said ATM/SONET Framer
2 provides Receiver and one Transmit interface to the
3 network at a SONET line rate of 155.52 Mbps(OC-3), 622.08
4 Mbps(OC-12) and 2488.32 Mbps(OC-48).

1 **3.** The system of claim 1 wherein said ATM and said
2 SONET interfaces operate on different clock frequencies
3 and represent two distinct clock domains,
4 and

5 the data interchange between the two said clock
6 domains is achieved by means of FIFO buffer elements and
7 associated control and status signals.

1 **4.** The system of claim 1 solves problems of
2 observability and controllability, due to constraints
3 stemming from the protection of proprietary data.

1 **5.** The system of claim 4 wherein said solution to said
2 problems of observability and controllability, is to
3 develop an accurate customized behavioral model,
4 and
5 said model offering sufficient parameters which can
6 be programmed to represent Framers of different vendors.

1 6. The system of claim 4 which in addition, offers
2 programmability, rich feature set, and two independently
3 configurable models, one each for said transmit side and
4 said receive side,

5 and

6 offers said programmability features of:

7 . SONET line rates (OC-Nc: N=1..48; OC-1=51.48
8 Mbps)

9 . Percentage of data bytes vs. overhead bytes
10 per row

11 . Delays associated with clock domain
12 synchronization

13 . FIFO depth and threshold (in terms of number of
14 cells)

15 . Byte or word count threshold within a cell
16 associated with FIFO status update

17 . UTOPIA Level-2/3

18 . Built-in performance checking

1 7. A computer based method employing a customizable
2 Simulation Model of an ATM/SONET Framer, for system level
3 verification and performance characterization, comprising
4 the steps of:

5 developing an accurate customizable behavioral model
6 that offer sufficient parameters which can be programmed
7 to represent Framers from different vendors;
8 providing two independently configurable components,
9 a Receiver and a Transmitter,
10 and

11 which provide testing with said multiple vendors of
12 Framers, by changing programmable parameters of said
13 model.

1 8. The method of claim 7, which in addition includes
2 the steps of:

3 said ATM/Sonet Framer provides Receiver and one
4 Transmit interface to the network at a SONET line rate of
5 155.52 Mbps(OC-3), 622.08 Mbps(OC-12) and 2488.32
6 Mbps(OC-48).

1 **9.** The method of claim 7 wherein said ATM and said
2 SONET in interfaces, operate on different clock
3 frequencies and represent two distinct clock domains,
4 and

5 data interchange between the two said clock domains
6 is achieved by means of FIFO buffer elements and
7 associated control and status signals.

1 **10.** The method of claim 7 solves problems of
2 observability and controllability, due to constraint
3 stemming from the protection of proprietary data.

1 **11.** The method of claim 10 wherein said solution to said
2 problems of observability and controllability, further
3 includes the steps of:

4 develop an accurate customized behavioral model,
5 and

6 said model offering sufficient parameters which can
7 be programmed to represent Framers of different vendors.

1 **12.** The method of claim 10 which in addition, offers
2 programmability, rich feature set, and two independently
3 configurable models, one each for said transmit side and
4 said receive side,
5 and

6 offers said programmability features of:

**A Customizable Simulation Model of an ATM/SONET Framer
for System Level Verification and Performance
Characterization**

ABSTRACT

5 This system represents a customizable simulation model of an ATM/SONET Framer for System Level Verification and Performance Characterization. An Asynchronous Transfer Mode (ATM) data processing ASIC interfaces with a Media Access Control (MAC) device that 10 presents an electrical data path interface, called Universal Test & Operations PHY Interface for ATM (UTOPIA), using ATM protocol on the ASIC side and simplex optical interfaces using Synchronous Optical Network (SONET) protocol on the network side. Such a MAC device, 15 commonly referred to as ATM/SONET Framer, provides one Receive and one Transmit interface to the network at various SONET line rates such as 155.52 Mbps(OC-3), 622.08 Mbps(OC-12), 2488.32 Mbps(OC-48), etc. The ATM and the SONET interfaces operate on different clock 20 frequencies and thus represent two distinct clocking domains. The data interchange between the two clocking domains is achieved via FIFO buffer elements and associated control and status signals.

Fig. 1

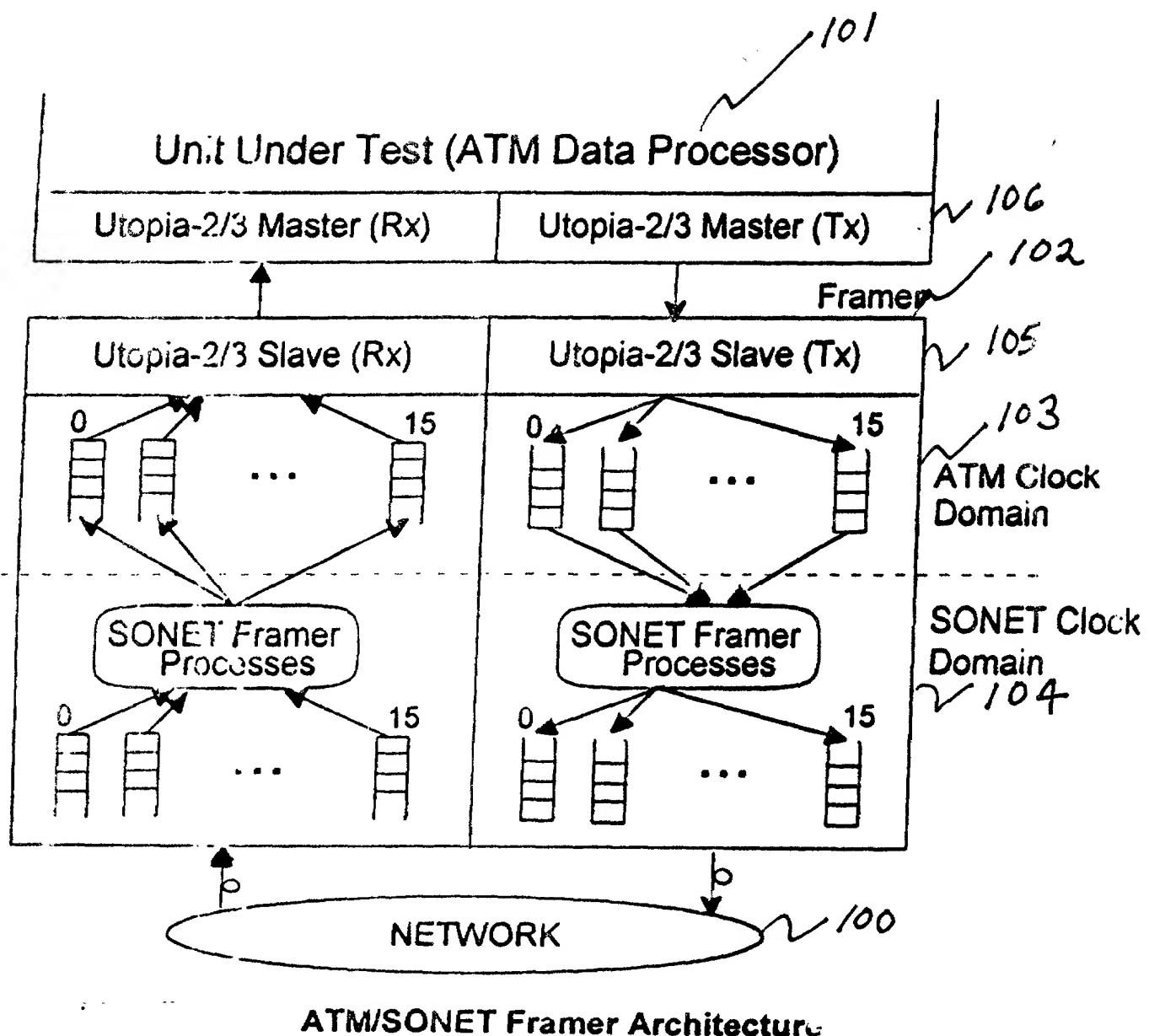
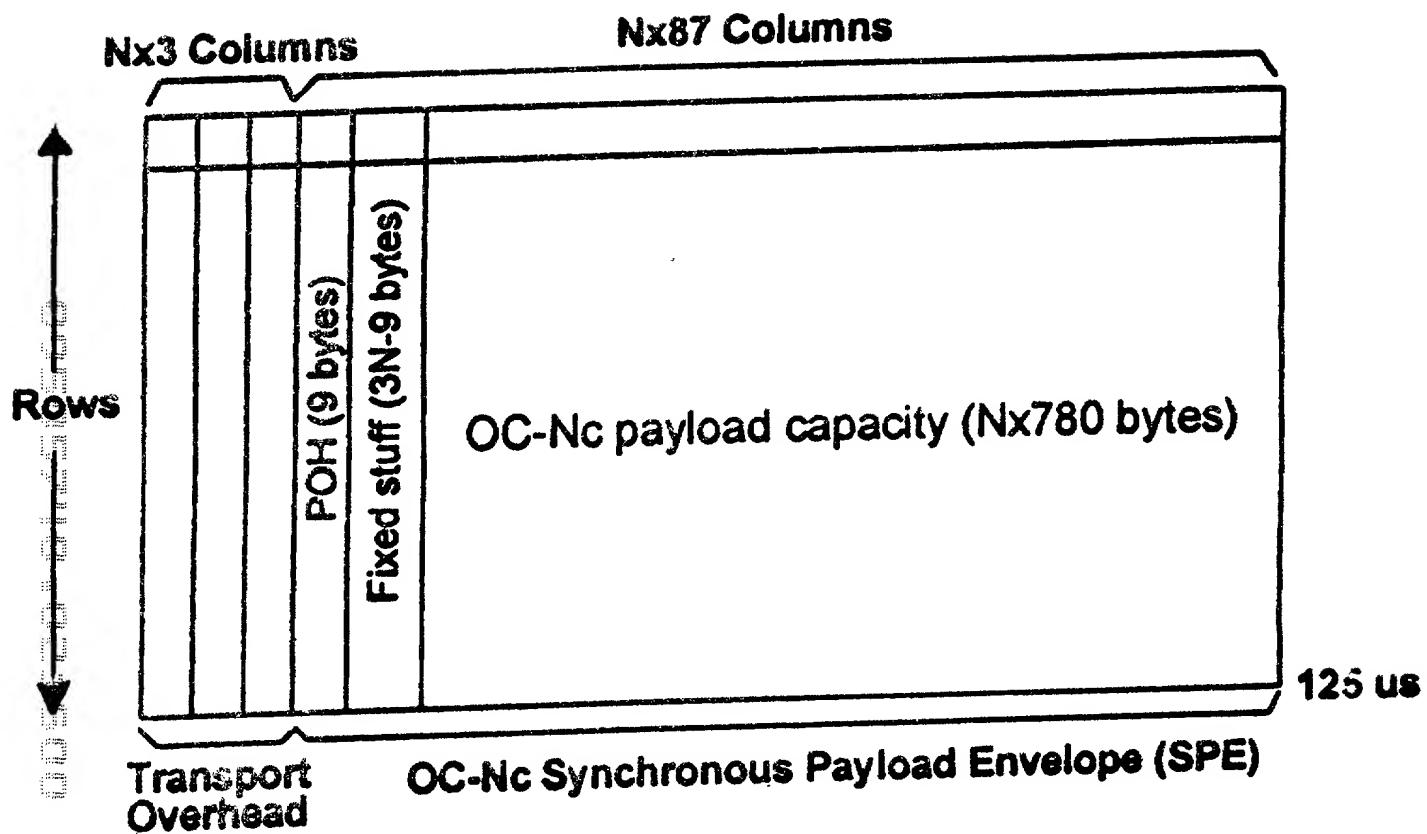


FIG 2



SONET OC-Nc Frame Structure

**DECLARATION AND POWER OF ATTORNEY
FOR PATENT APPLICATION**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name; I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**Customizable Simulation Model of an ATM/SONET Framer for
System Level Verification and Performance Characterization**

the specification of which is identified by the attorney (IBM) Docket Number appearing above.

I hereby state that I have reviewed and understand the contents of the above- identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)

<u>Number</u>	<u>Country</u>	<u>Day/Month/Year</u>	<u>Priority Claimed</u>
---------------	----------------	-----------------------	-------------------------

I hereby claim the benefit (a) under Title 35, United States Code, §119(e) of any U.S. application listed below and identified as a provisional application or (b) under Title 35, United States Code, §120 of any U.S. application listed below and not identified as a provisional application, and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior U.S. application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information material to the patentability of this application as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application

Prior U.S. Applications

<u>Serial No.</u>	<u>Filing Date</u>	<u>Status</u>
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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

As a named inventor, I hereby appoint the following attorneys and/or agents to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: Daniel E. McConnell, Reg. No. 20,360; Kenneth A. Seaman, Reg. No. 28,113; Joscelyn G. Cockburn, Reg. No. 27,069; Gerald R. Woods, Reg. No. 24,144; John D. Flynn, Reg. No. 35,137; Horace St. Julian, Reg. No. 30,329; Joseph C. Redmond, Jr., Reg. No. 18,753; John E. Hoel, Reg. No. 26,279; Christopher A. Hughes, Reg. No. 26,914; and Edward A. Pennington, Reg. No. 32,588.

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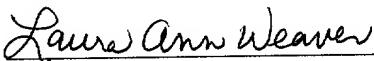
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